



Lessons learned from mapping soil moisture with radar remote sensing at WGEW

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Soil moisture maps used for:



- Pest management
- Irrigation schedules
- Biomass production
- Ground water models
- Erosion models
- CO₂ emission models

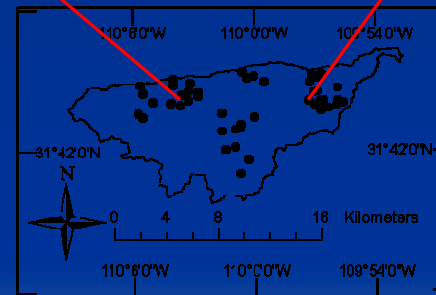


The Radar Advantage

- Active sensor with high spatial resolution
 - 6 to 25 m
- Day or night operation
- Physical models describe scattering
 - IEM and others
- Radar satellites currently in orbit
 - Radarsat, ERS
- Depth penetration
 - 1 to 10 cm depending on wavelength and soil moisture



Study Area



Arizona

Components of backscatter

$$\sigma^0 = f(\Theta_v, \text{rough})$$



Scanning
LiDAR



Remote
sensing



Models

1) Integral Equation Method (IEM)

- models radar and its interactions with surfaces
- Invert backscatter to obtain Θ_v

if $\sigma^0 = f(\Theta_v, \text{rough})$

then $\Theta_v = f(\sigma^0, \text{rough})$

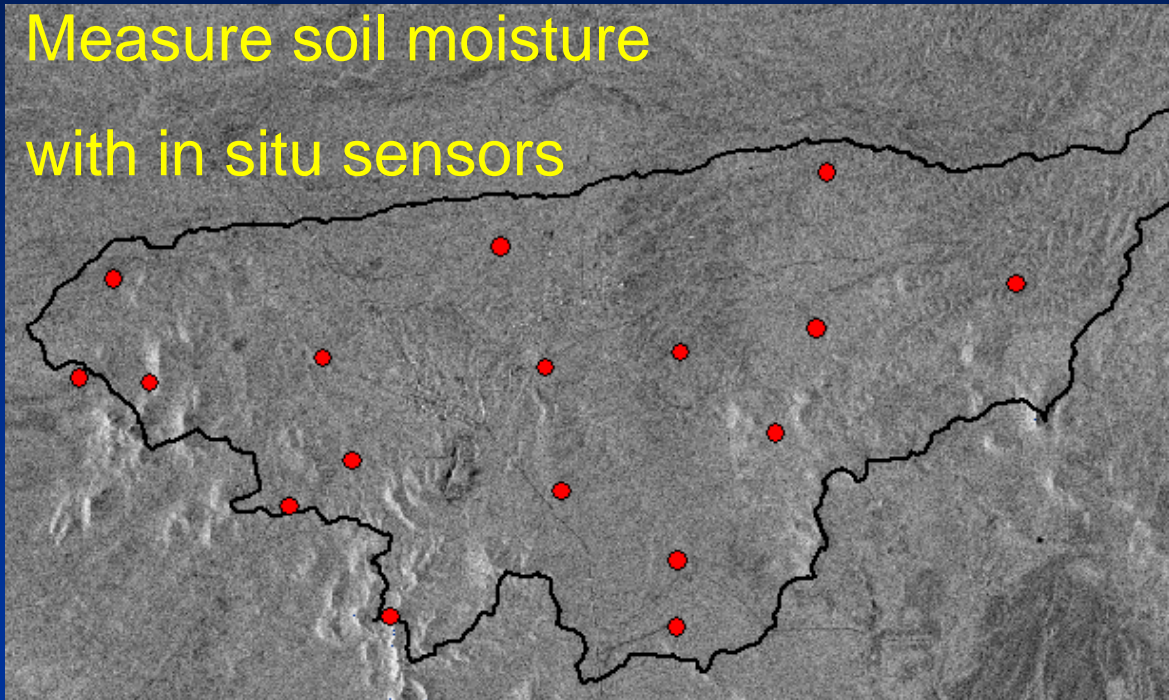
2) Delta Index

- $\Delta\text{-index} = \text{abs}[(\sigma^0_{\text{wet}} - \sigma^0_{\text{dry}}) / \sigma^0_{\text{dry}}] * 100$,
- σ^0_{dry} = average radar backscatter of dry scene,
- σ^0_{wet} = average radar backscatter of wet scene.



General approach

Measure soil moisture
with in situ sensors



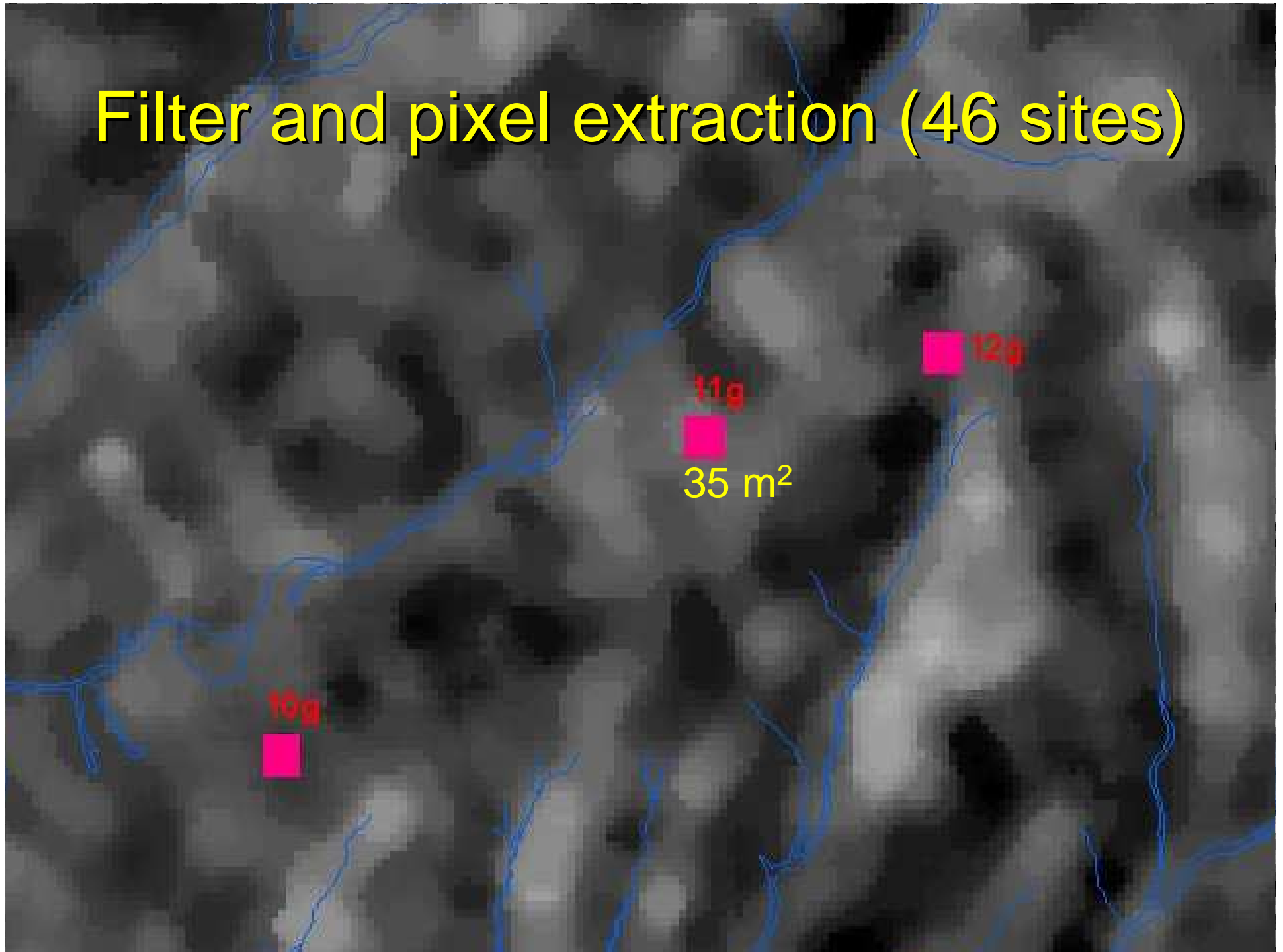
Additional measurements made with
portable dielectric probes at times of satellite
overpass



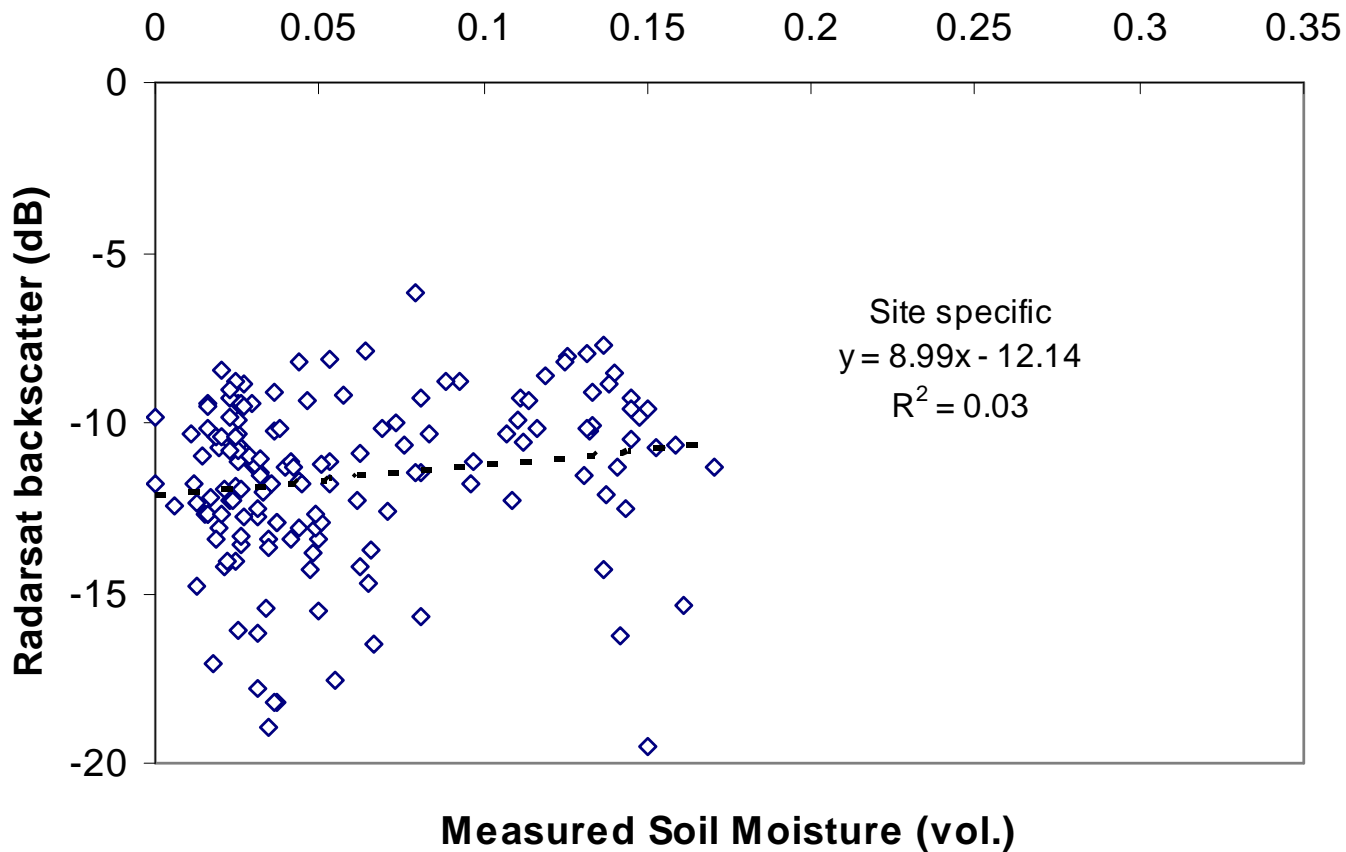
Pin meter used to measure
surface roughness for use with IEM
scattering model



Filter and pixel extraction (46 sites)



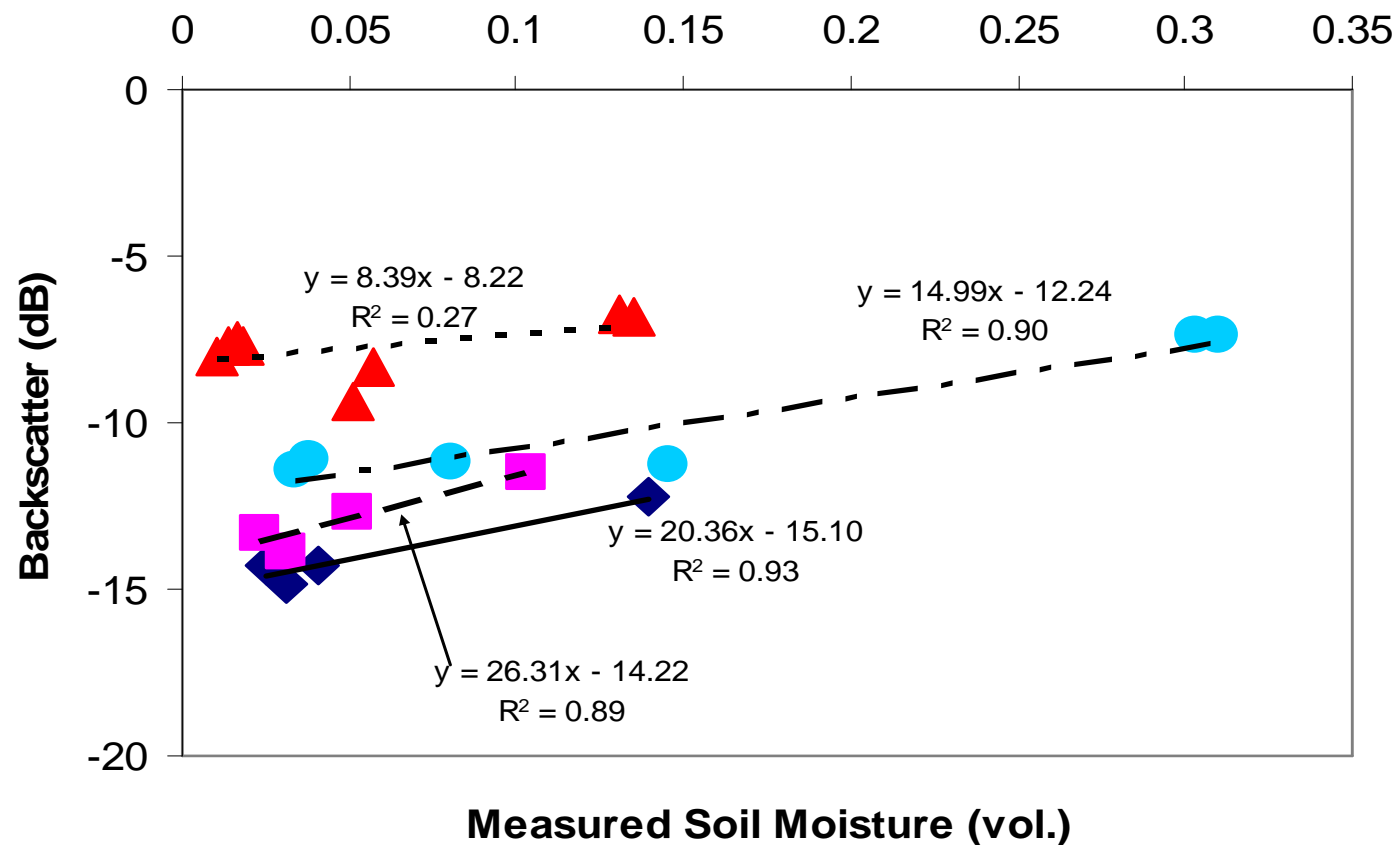
Site specific relationships not good



◇ All sites, all dates

- - - Linear (All sites, all dates)

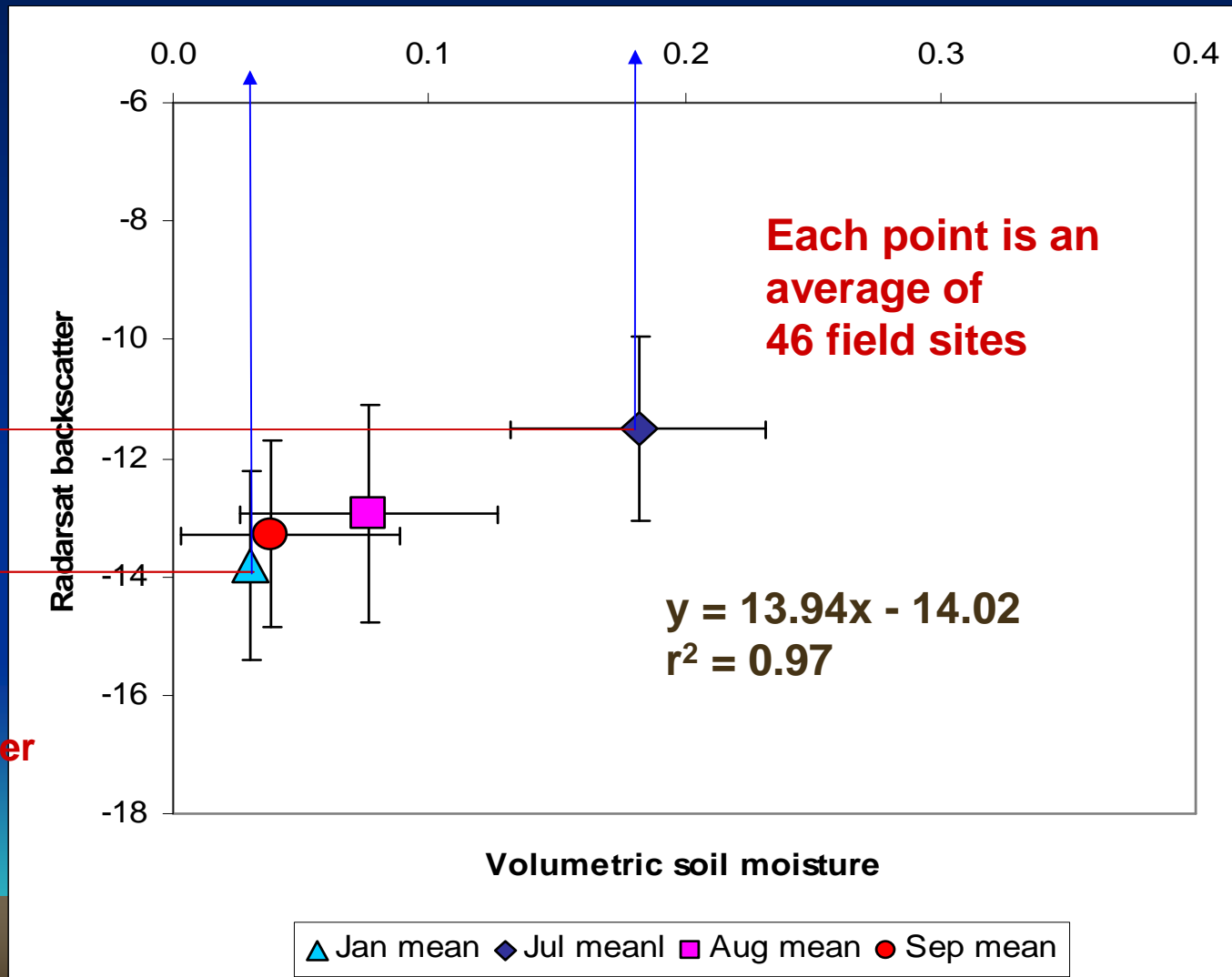
Habitat scale better



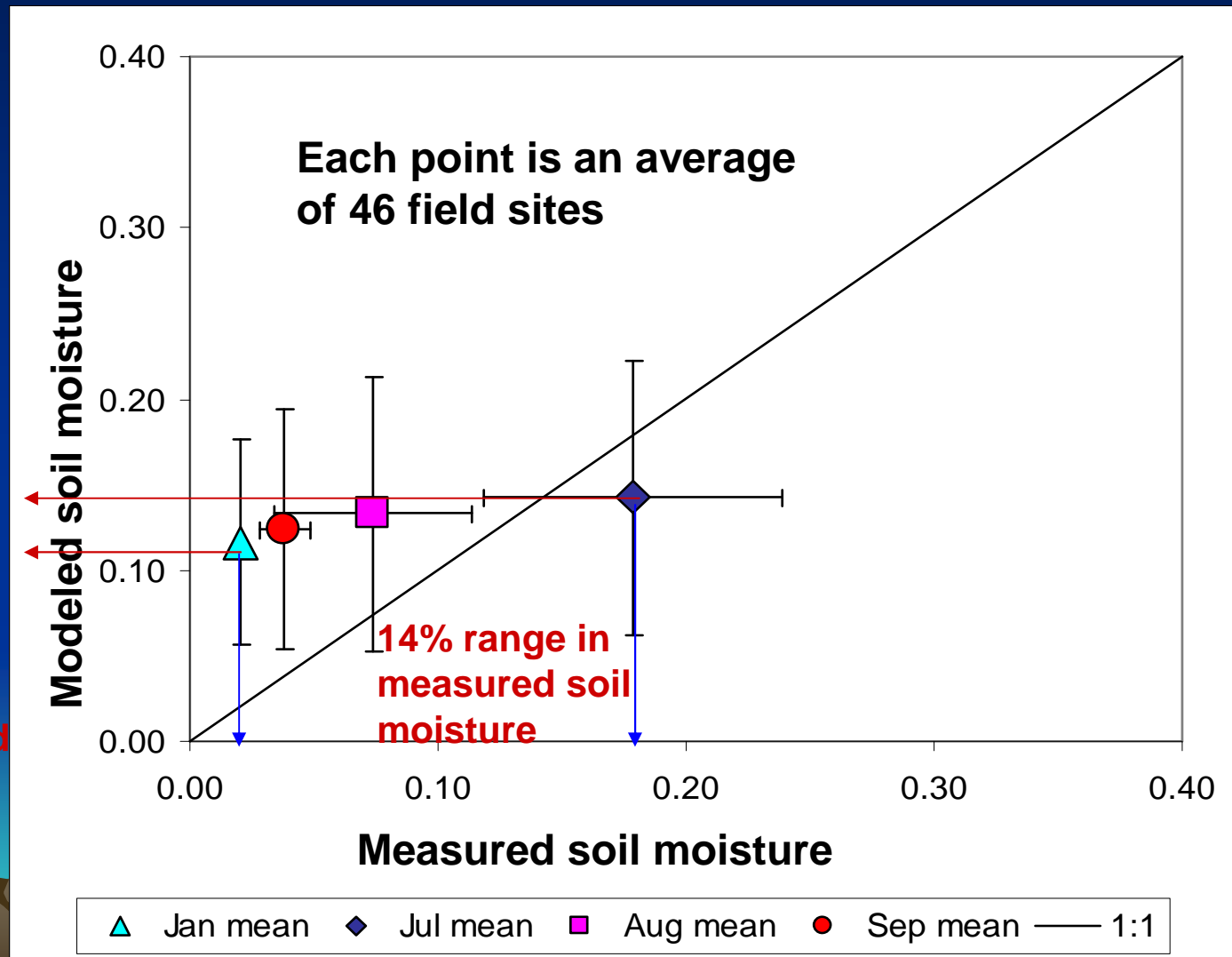
Watershed scale best but...

14% range in soil
moisture

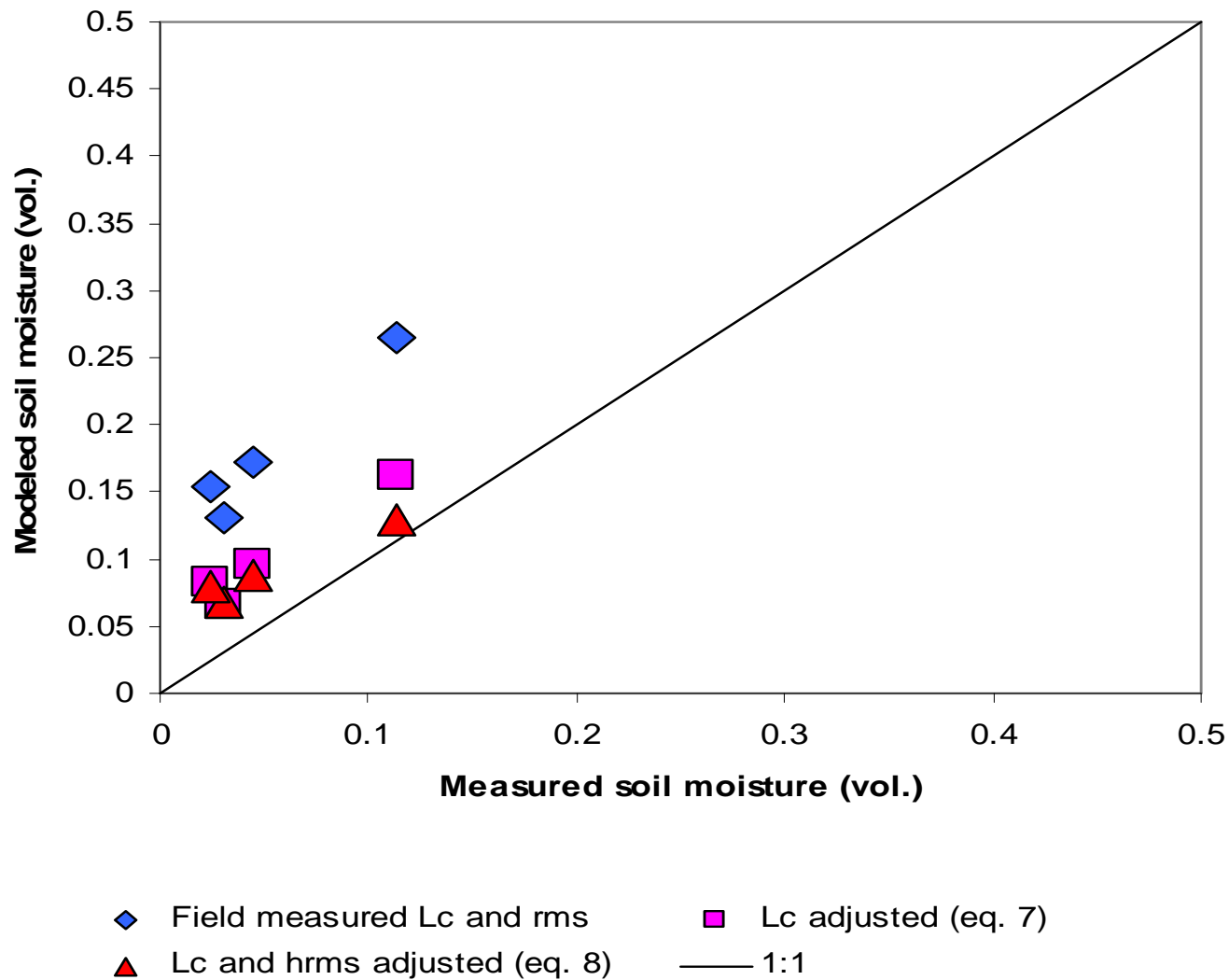
2.3 dB
range in
backscatter



The narrow range in backscatter makes inversion difficult



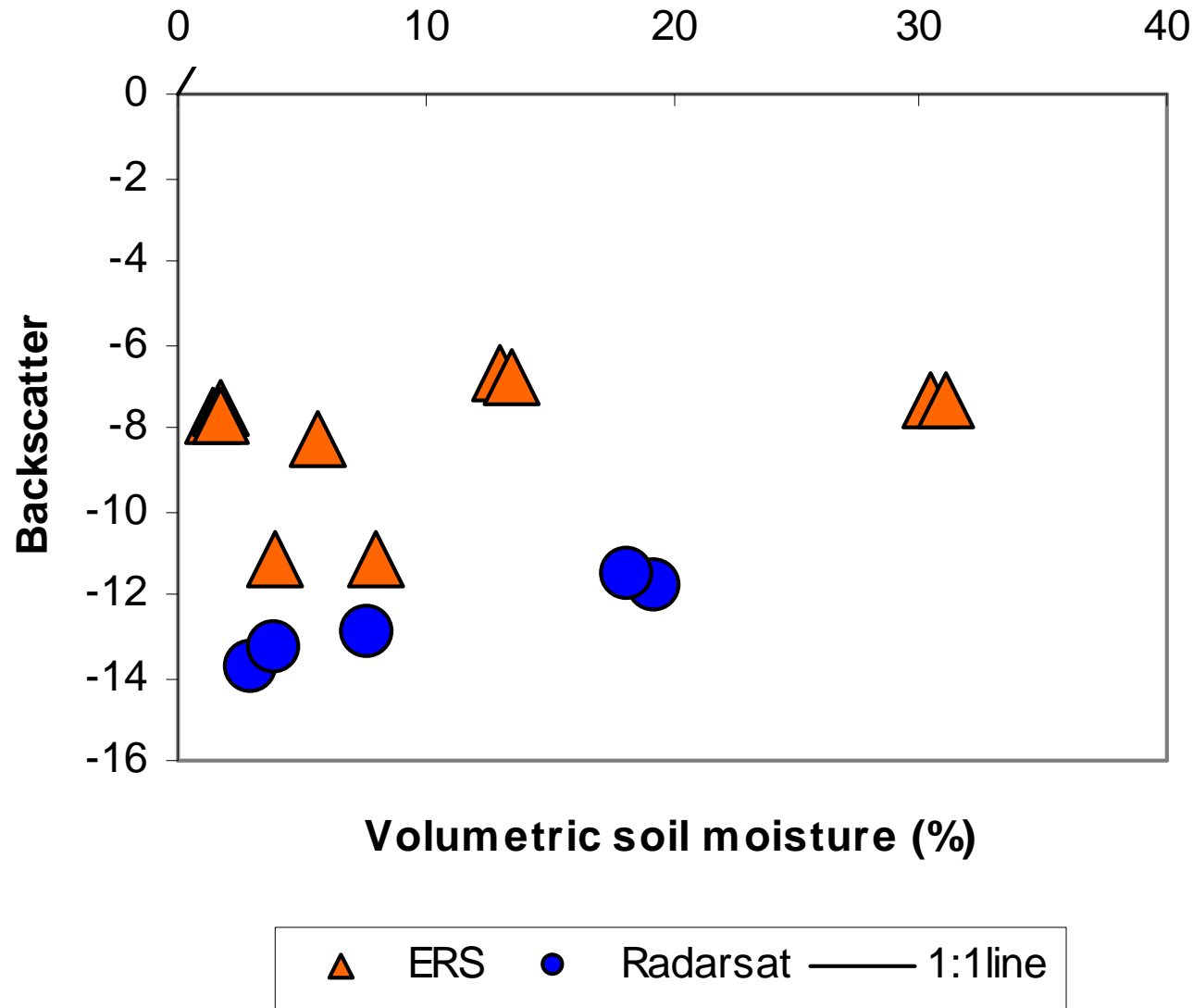
Roughness adjustments help, but...



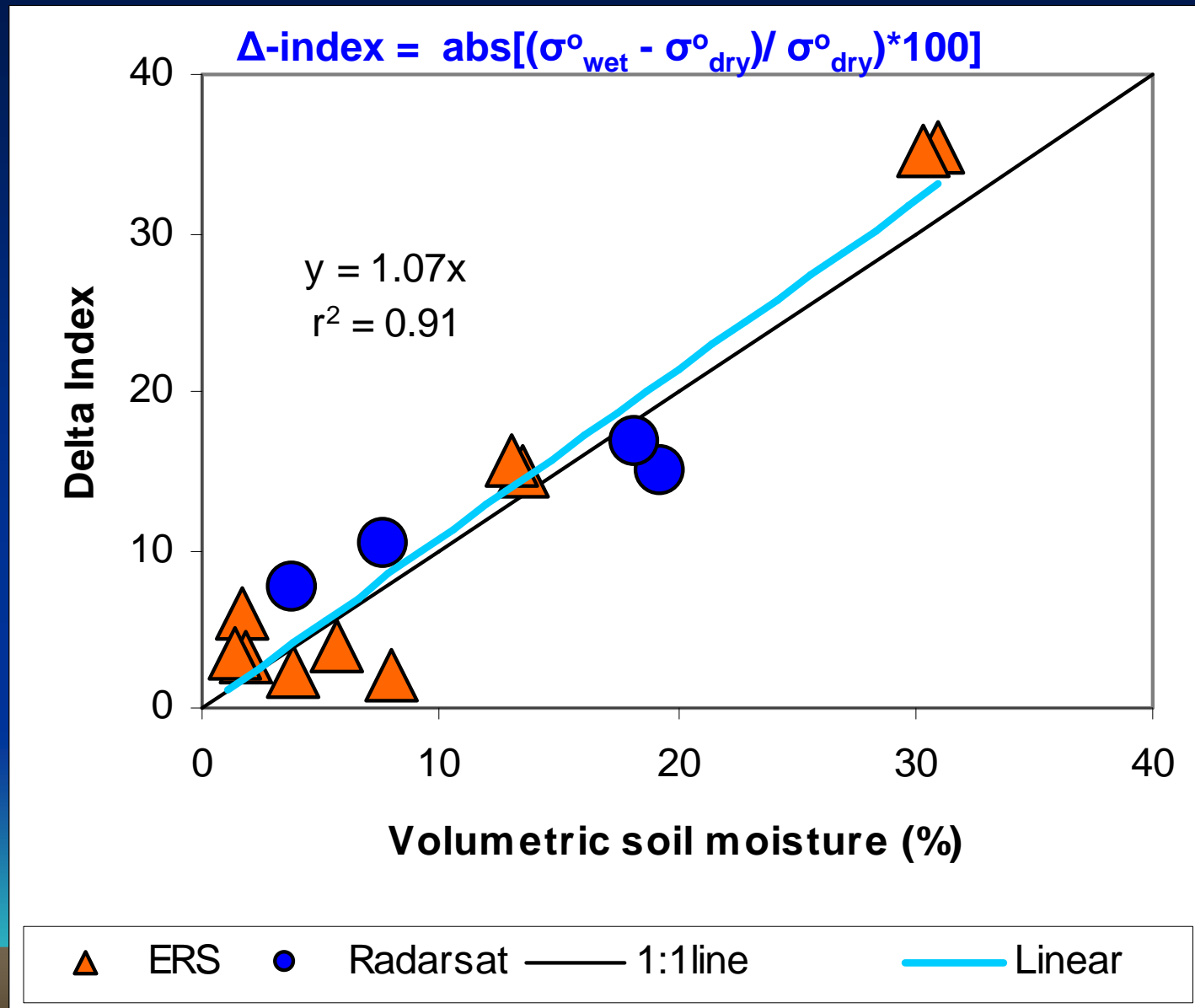


Roughness is difficult to
characterize

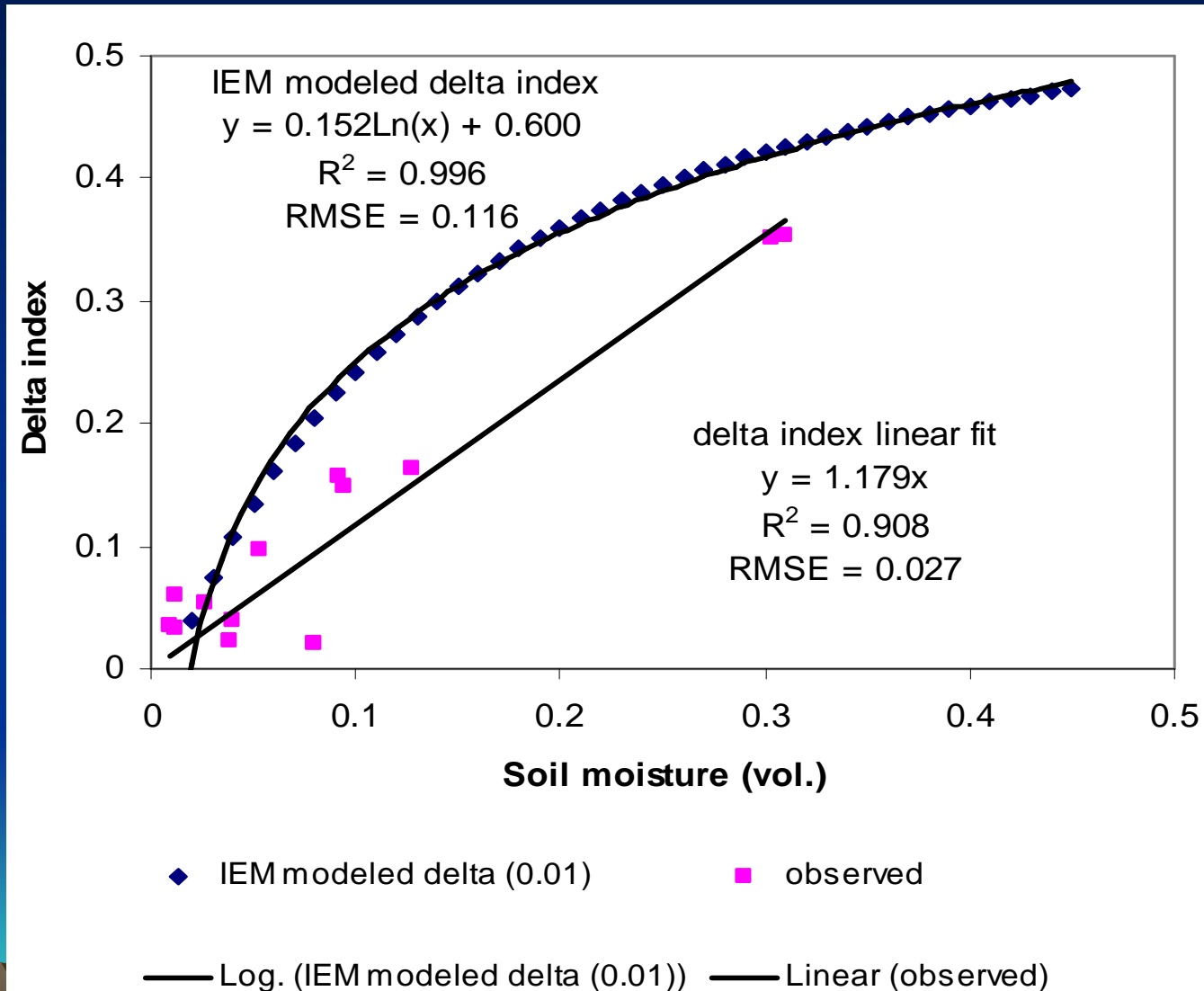
A new approach – The delta Index



Delta index calculated from backscatter

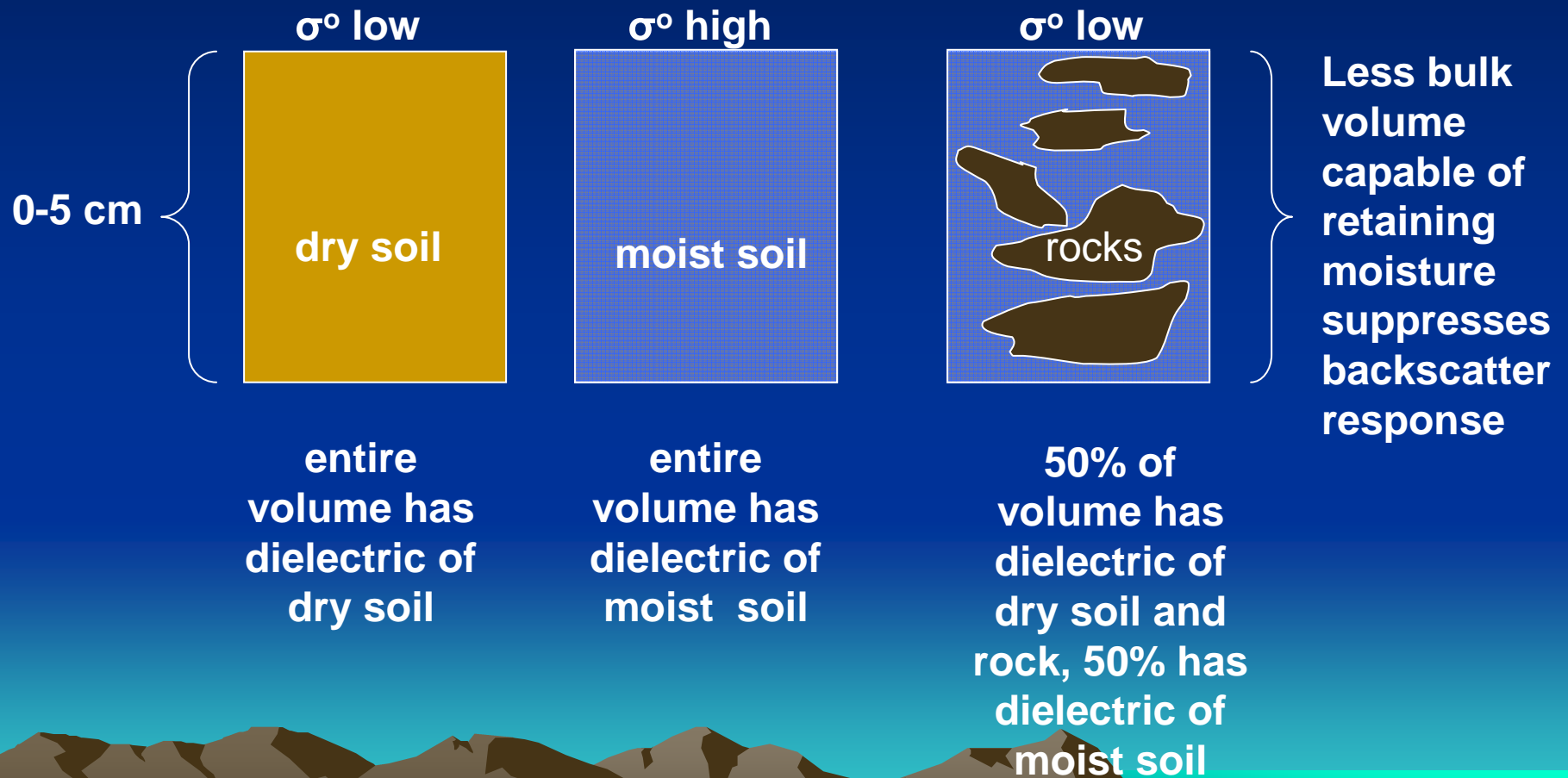


Does IEM reproduce delta index results?



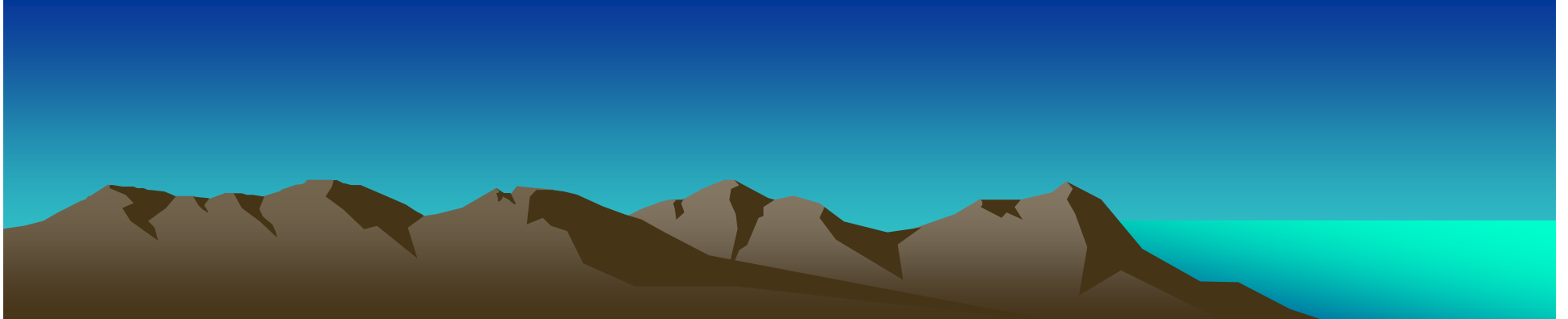
In scattering models rocks matter

wet or dry, rocks have dielectric
similar to dry soil



Explanation of Δ -index

- Δ -index implicitly accounts for roughness, vegetation, slope, and rock fragments because these do not change between image acquisitions
- Sensitive to proportional change in moisture

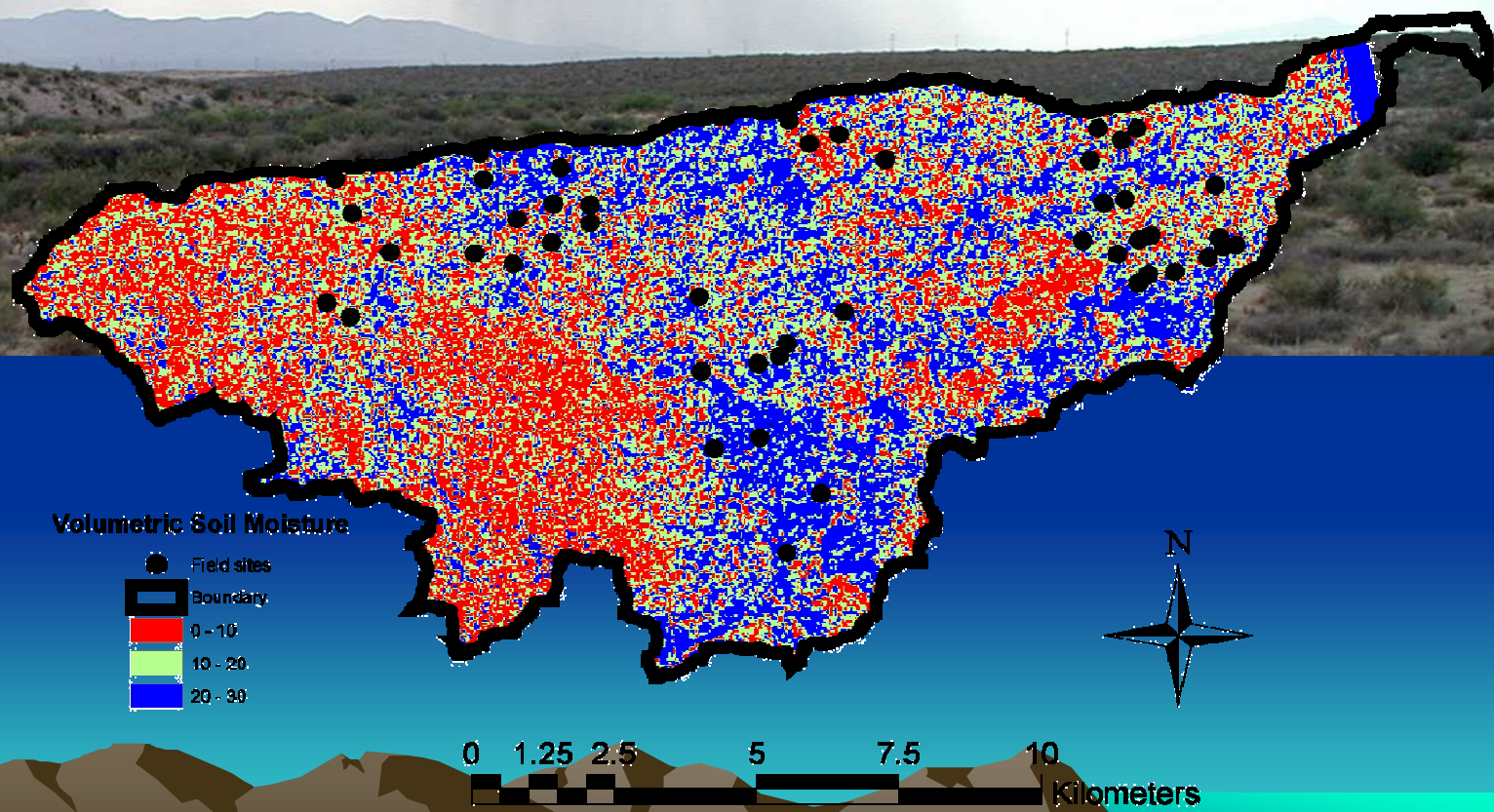


Advantages of Δ -index

- Δ -index approximates the 1:1 line
- Can be used with both ERS and Radarsat
- Easy to implement and requires only
 - dry scene and unchanging roughness
 - very good image to image registration
- Does not require roughness measurements



Delta index map of soil moisture

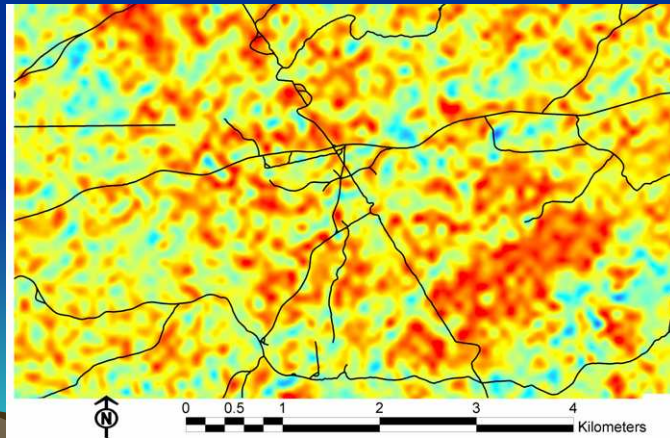
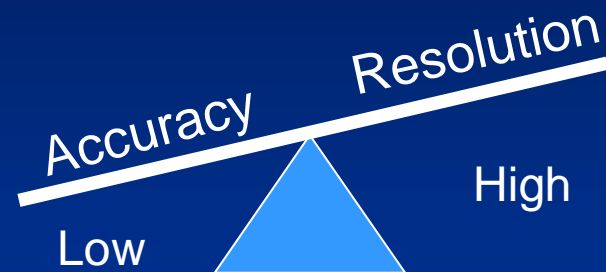
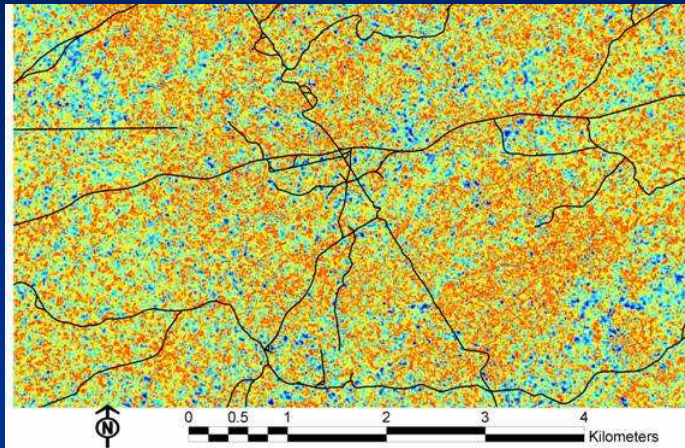


Regardless of model used speckle still causes trouble

- There are trade-offs between accuracy and scale.
- Over smaller areas estimates of soil moisture become less reliable.

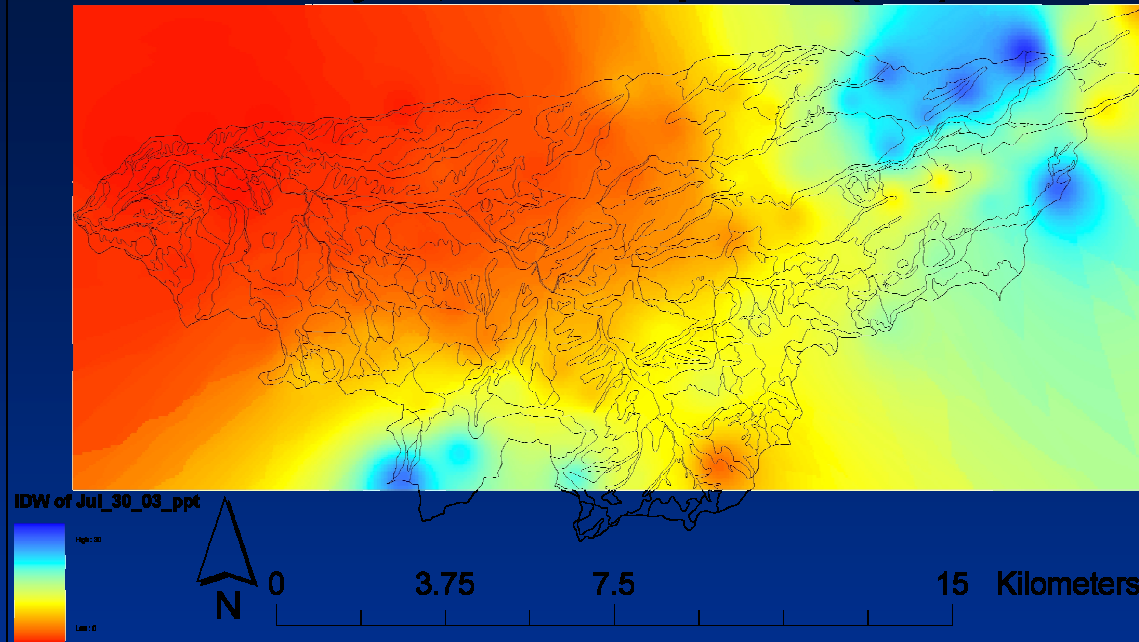


Accuracy and Resolution



This is primarily due to image speckle.

July 30, 2003 Precipitation (mm)



July 30, 2003

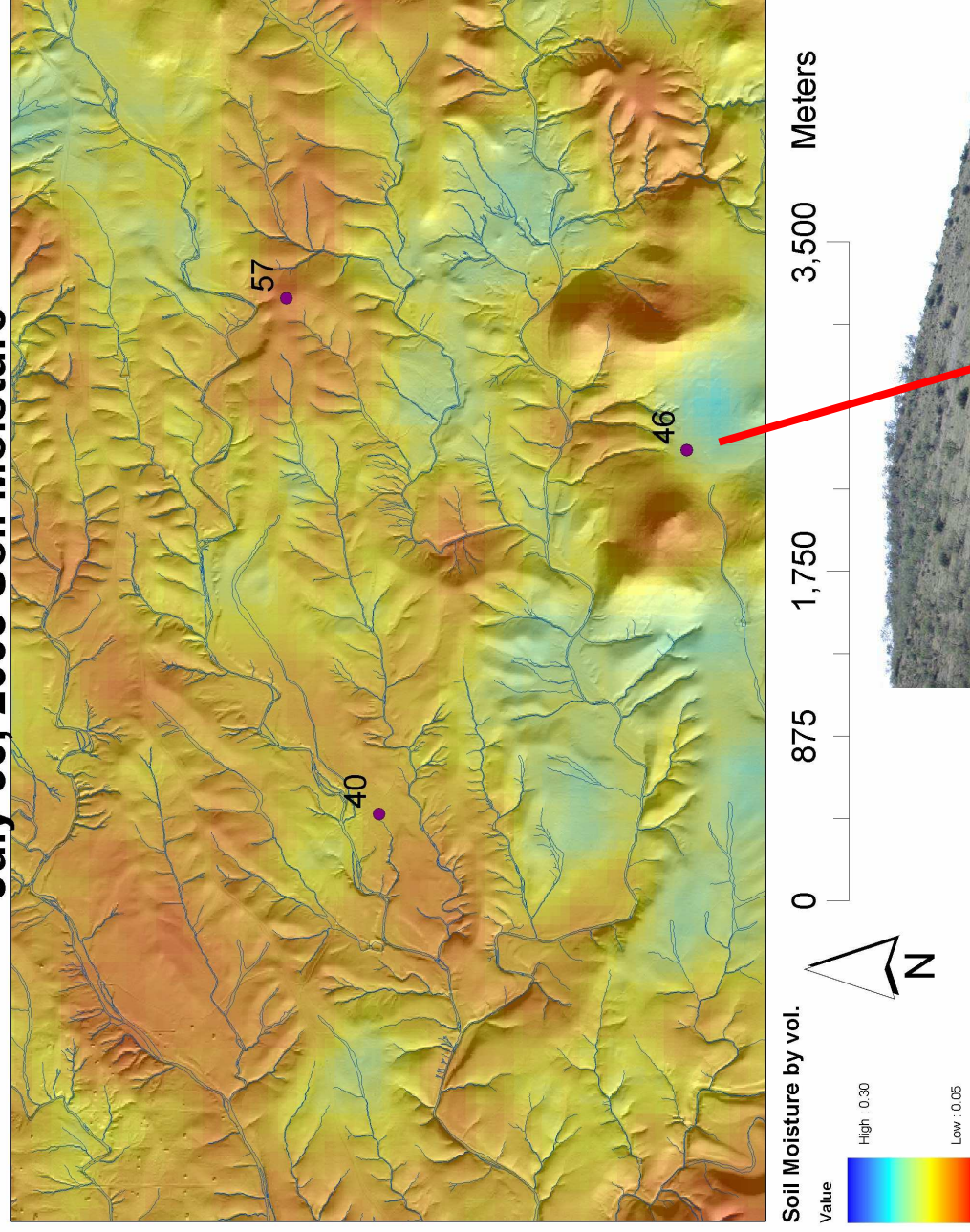
Precipitation (mm)

July 30, 2003 Soil Moisture

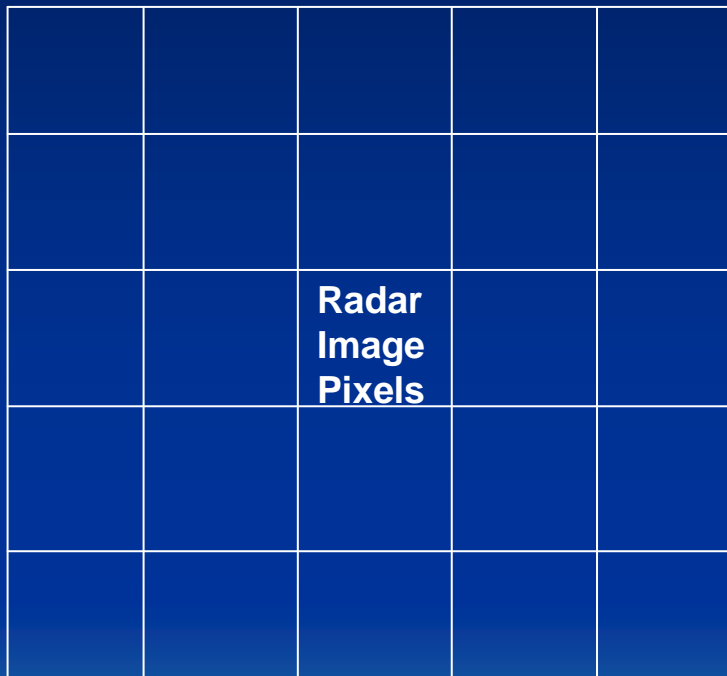


Soil moisture (vol.)

July 30, 2003 Soil Moisture



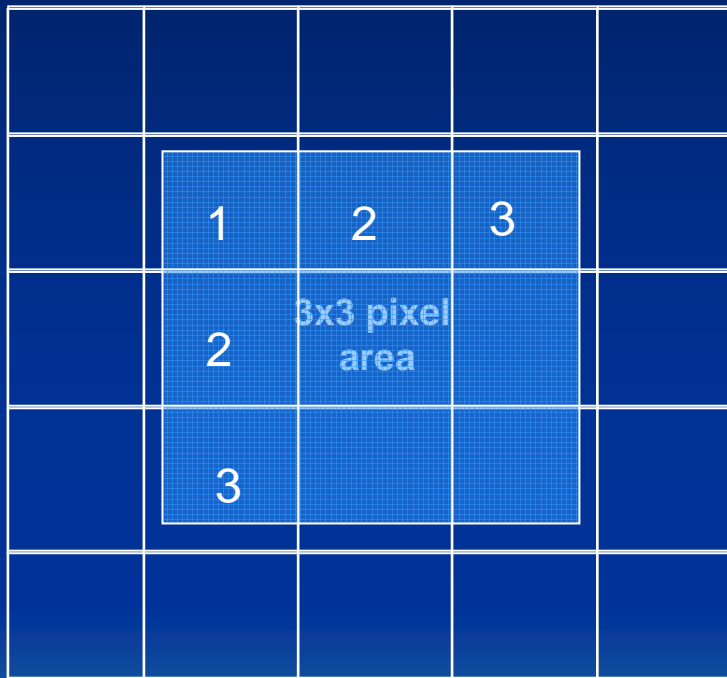
Determining appropriate spatial scale - region growing algorithm



Grows a region
around field site

Computes
statistics (mean,
STDV, and CI)

Region Growing algorithm



Grows a region
around field site

Computes
statistics (mean,
STDV, and CI)

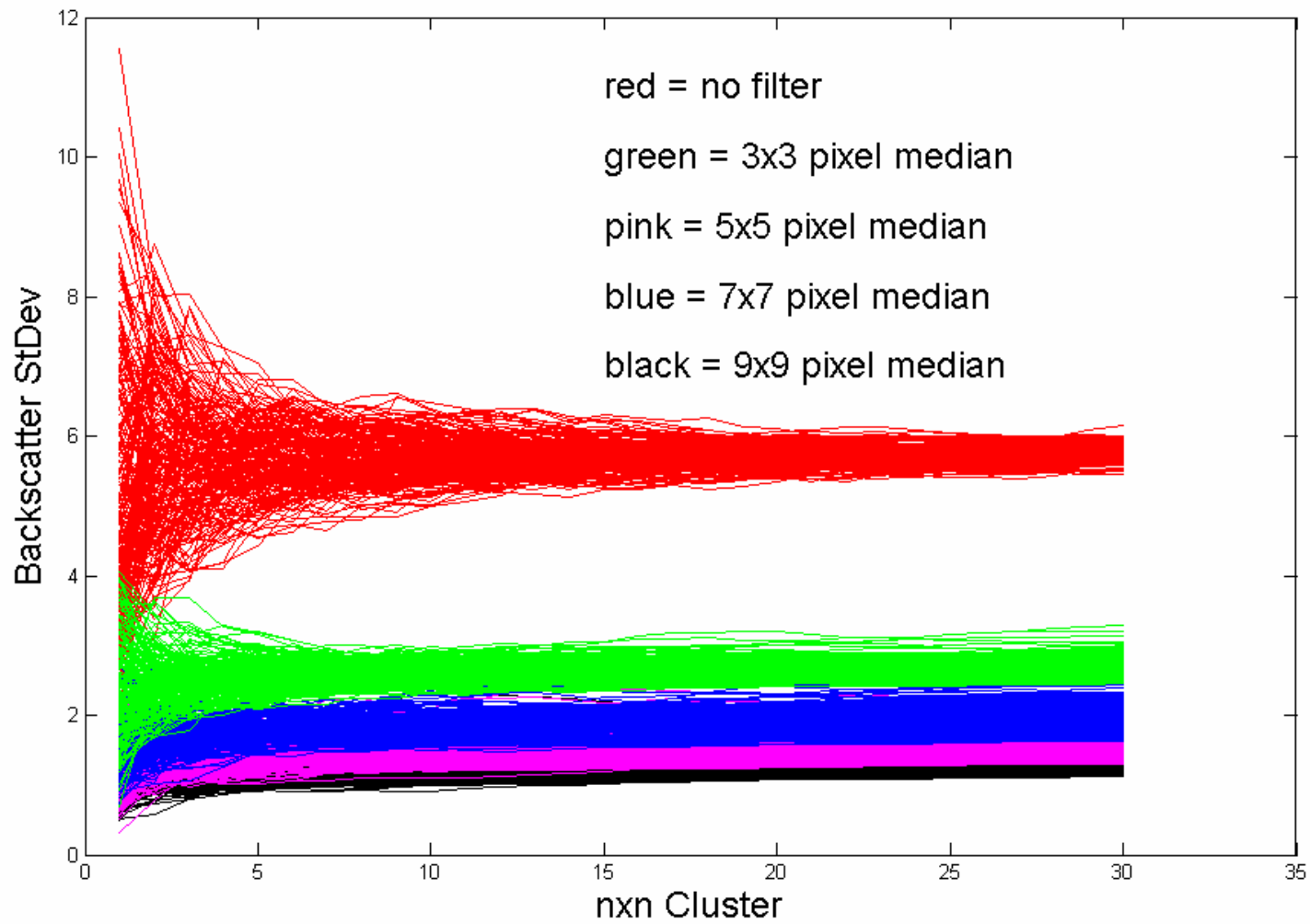
Region Growing algorithm

1	2	3	4	5
2				
3		5x5 pixel area		
4				
5				

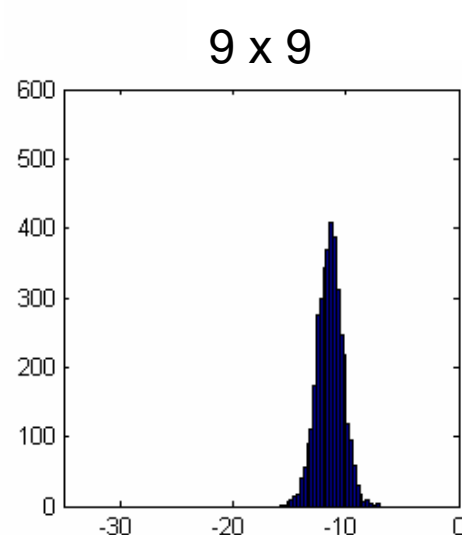
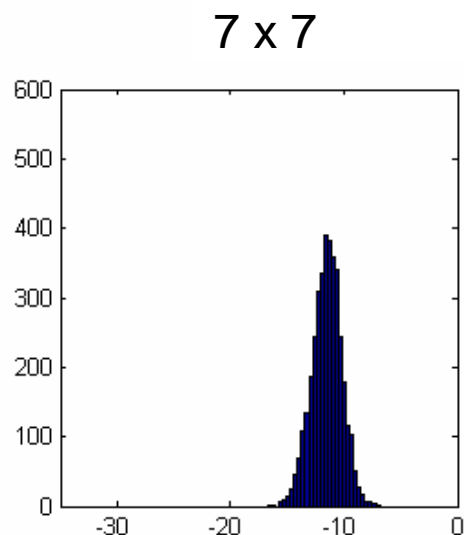
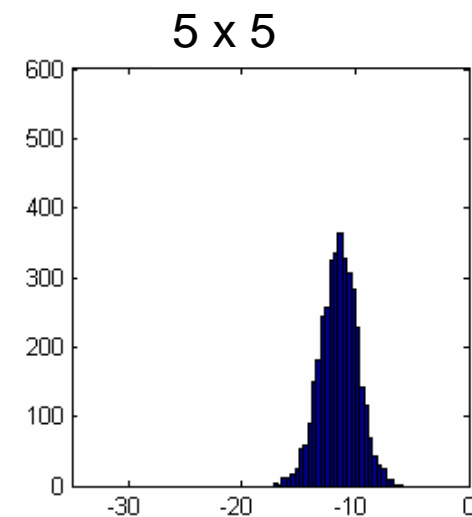
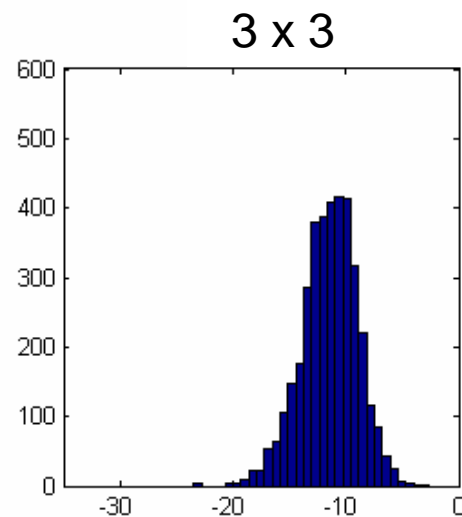
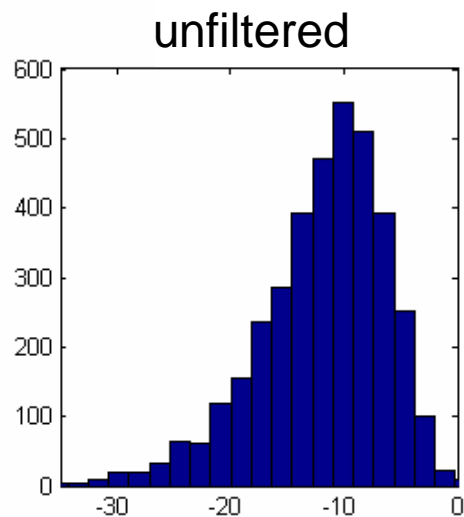
Grows a region
around field site

Computes
statistics (mean,
STDV, and CI)

Filtering and spatial averaging reduce backscatter variability



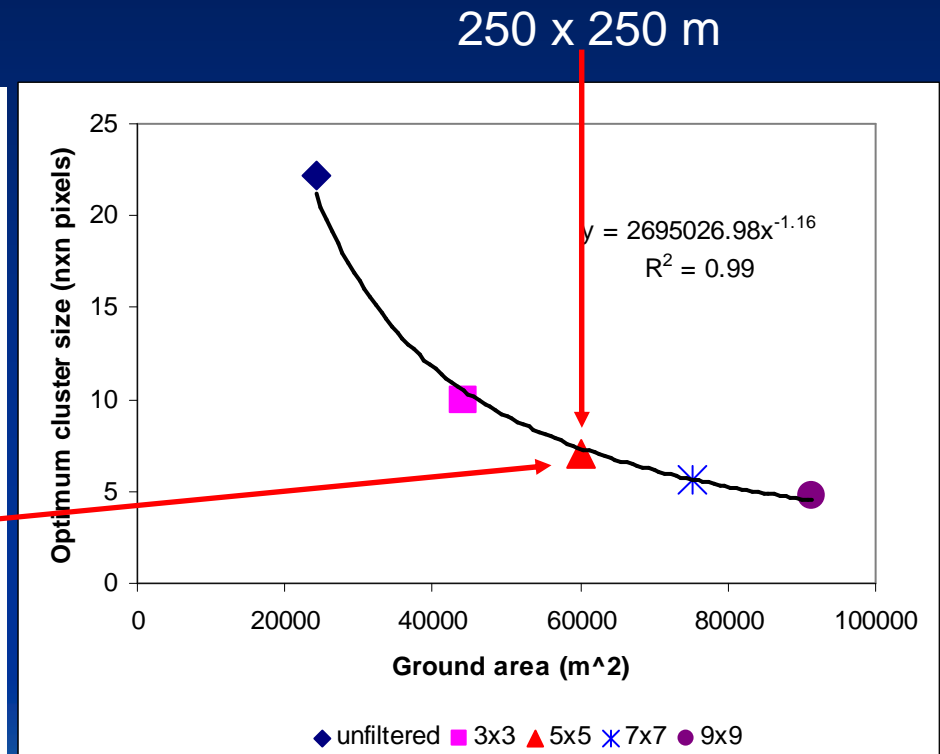
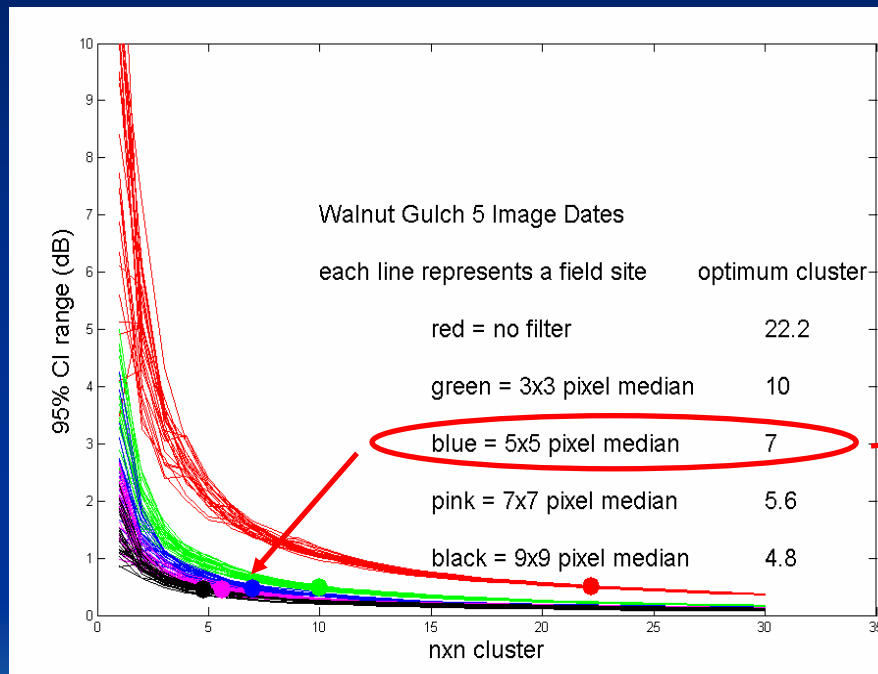
Block filters minimize effect of outlying speckle



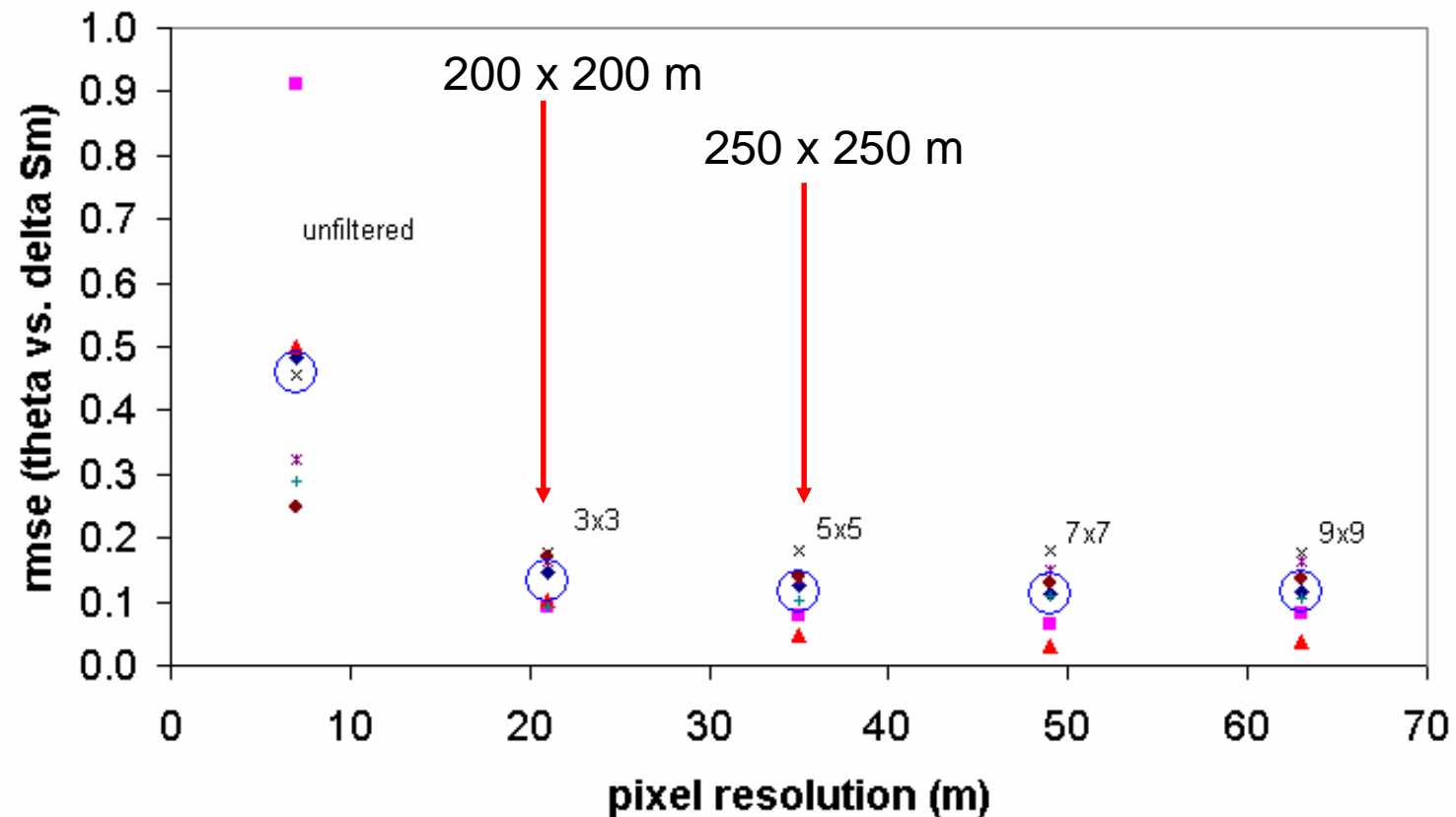
- highlight central tendency
- distribution more normal
- outlying values eliminated

42 field sites, 30x30 pixel mean
Uniformly dry image date = Aug 04_02, WGEW

Optimum pixel cluster and effective ground area



Spatial scale vs. model accuracy



◆ AZ 30-Jul-03 ■ AZ 23-Aug-03 ▲ AZ 16-Sep-03 × AZ 4-Aug-02
* GA 27-Feb-04 ♦ OK 13-Mar-04 + OK 6-Apr-04 ○ 3 watershed avg

Conclusions

Revisit “The Radar Advantage”

- Day or night operation
 - **Still true**
- Radar satellites currently in orbit
 - Radarsat, ERS
 - **More satellites = more viewing opportunities**
- Depth penetration
 - 1 to 10 cm depending on wavelength and soil moisture
 - **Still the best of any orbiting sensors**
- Physical models describe scattering
 - IEM and others
 - **IEM has limits due to roughness and rocks**
 - **Delta index is a good alternative with considerable promise**
 - Easy to implement
 - Doesn't require roughness
 - Active sensor with high spatial resolution (6 to 25 m)
 - **Tradeoff between resolution and accuracy**
 - **Speckle limits accurate estimates to about 200 m**



Thanks!

- This research was funded by US Army ERDC-TEC and USDA-ARS